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JAMES BERNARD RUSSELL: SCHOLAR, COLLABORATOR, MENTOR

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Dr. James B. Russell was a rumen microbiologist who became a legend in the field of animal and dairy science, both for his towering intellect and his unique personality. The latter has provided fodder for many legendary (even apocryphal) stories in the scientific community, and most of the stories are probably true. In this presentation, we hope to give you a sense of Jim both as a scientist and as a complex person, and why he has left such a mark on the fields of ruminant nutrition and rumen microbiology.

Jim grew up on a dairy farm in upstate New York. He received a B.S. degree from Cornell University in 1973 and M.S. and Ph. D. degrees from the University of California at Davis in 1974 and 1978, respectively. He began his professional career as an Assistant Professor at the University of Illinois in 1978. Jim joined the Agricultural Research Service of the USDA in 1981 and returned to Ithaca, NY where he served as a microbiologist in the Plant, Soil, and Nutrition Laboratory until his untimely death on September 20, 2009. For over 25 years, in addition to his federal duties, Jim held a courtesy appointment as Professor of Animal Science and Microbiology at Cornell University. He trained over 40 undergraduate, graduate and post-doctoral students. He received numerous ARS outstanding performance awards, including the North Atlantic Area Scientist of the Year, and the 1994 American Dairy Science Association/American Feed Industry Association (AFIA) Award. In 1999, he was elected to the American Academy of Microbiology via a "highly selective, peer review process, based on scientific achievement and original contributions that have advanced microbiology." In 2001, the American Society of Information Science and Technology named him to their list of World's Most Productive Scientists (an elite group of the top 0.5% scientists based on publication output). In 2002, Jim self-published his book, "Rumen Microbiology and Its Role in Ruminant Nutrition", which was aimed as an overview to provide a service to the broadest possible audience, and today is one of the most concise approaches to analyzing the relationship between the ruminant and its microbial consortium. In 2004, the USDA/ARS Grade Evaluation System promoted him from GS-15 to ST (super-grade), an honor bestowed upon fewer than 1% of its career scientists. In 2005, Jim received the AFIA Award in Ruminant Nutrition Research through the American Society of Animal Science (ASAS). In 2008, Jim was the recipient of the Morrison Award from the ASAS, a professional capstone award in recognition of his outstanding contributions to the field of animal production, Jim's stature was further demonstrated by the fact that numerous foreign scientists selected his laboratory as a site for their sabbaticals. Jim served on the editorial boards of *Applied and Environmental Microbiology*, *Microbiology* and the *Journal of Dairy Science*. He chaired or co-chaired numerous scientific meetings, received numerous extramural grants, and was a syndicated columnist for

Farm Progress Magazines. An objective measure of the breadth of Jim's impact is demonstrated by a SCOPUS search, which displays more than 6,000 citations (excluding self-citations) over the past 15 years.

Even after all his awards and world travel, at heart, Jim would always be a "dairy kid". He grew up on a New York dairy, but his early experience (and his father's) in California also influenced his personality. The main trait this upbringing provided him was the ability to focus on the "big picture" – how everything fit together. One of his cardinal rules was to always be able to explain your research to the guy driving a tractor on a dairy farm, or to a pen rider in a feedlot. If you could not get across to that person why your research was important, then you needed to rethink what research you were performing. He applied this explanatory approach to such seemingly esoteric concepts as the electrochemistry behind ionophore function (Russell, 1987; Kajikawa and Russell, 1992), energy utilization, enzymes and metabolism of bacteria (Van Kessel and Russell, 1992; Bond and Russell, 1996, 1998), as well as how to feed cattle more efficiently (Fron et al., 1996; Diez-Gonzalez et al., 1998; Russell, 1999; Russell and Rychlik, 2001).

Jim's mind worked in ways unlike other peoples' minds. He had a special ability to understand mechanistic details at small scale, without losing sight of the big picture of feeding the animal or the economics of dairy production. This is probably what made him such an asset to a modeling effort like the CNCPS, which required breaking down complex phenomena into individual equations that, when combined, were still relevant to the animal. This skill in thinking mathematically and biologically at multiple levels, directions, scales while still maintaining a focus on the big picture also allowed him to be a successful collaborator with his fellow microbiologists. One of us (PJW) recalls a personal experience, relating Jim's contribution to our understanding of the crossfeeding of nutrients between ruminal bacteria (Wells et al., 1995). In the course of determining some fundamental growth parameters of ruminal cellulolytic bacteria, I was attempting to determine the kinetic constants for growth of individual cellulolytic species on each of the compounds in the oligomeric series of cellulose hydrolysis products. This was quite simple for glucose and for cellobiose, as both are readily available and relatively inexpensive. But the individual pure cellodextrins (cellotriose, cellotetraose, etc.) are extremely expensive --- several dollars per milligram, because they are very difficult to isolate from cellulose hydrolysis mixtures at a preparative scale. To get around this, I had this idea to grow the bacteria in continuous culture on a cellodextrin mixture prepared by partial acid hydrolysis of cellulose. By measuring concentrations of each component of the mixture in the inflow and outflow of the chemostat, I hoped to calculate uptake rates for each of the individual cellodextrins. To test the idea, I had my graduate student, Yan Shi, first grow *Fibrobacter succinogenes* on cellobiose, and measure cellobiose concentrations in the inflow and outflow of the chemostat. She observed, as we expected, that cellobiose was consumed in the chemostat, but to our surprise, she observed that the chemostat effluent contained substantial amounts of the longer oligomer, cellotriose. I happened to mention this to Jim. He jumped on it immediately, proposing that cellotriose was synthesized exergonically by an intracellular cellodextrin phosphorylase and then effluxed from the cells to maintain the equilibrium

in the direction of cellodextrin synthesis. In addition, he recognized that this "cellodextrin efflux" can serve as a means of cross-feeding cellodextrins to both noncellulolytic and planktonic cellulolytic bacteria (both of which can sometimes grow better on cellodextrins than on glucose). A few weeks of collaborative experiments proved the concept. Thus, the idea of using the chemostat to characterize fermentation of individual cellodextrins had to be abandoned, but in its place we had a more general, "bigger-picture" cross-feeding story to tell.

Another facet of Jim's persona was molded on the dairy farm through the 1950's and 60's: An insecurity that manifested itself in a tremendous drive and work ethic, and a scientific restlessness that is a hallmark of the "great ones". But Jim's insecurity also made him feel that he had to prove himself, at any cost ---- which was often his undoing in his personal relationships. Jim revered Bob Hungate and Marvin Bryant, who together truly founded the study of the microbiology of the rumen, and Jim always gave them their due credit and recognition. However, he craved to be on the Mount Rushmore of Rumen Microbiology with them. He had a need to be esteemed for his science and his science alone, because for him respect could only be based on scientific abilities and accomplishments; no other criterion for greatness was acceptable. This peculiar naivety with regard to basic social skills stands in stark contrast to Jim's scientific brilliance (discussed in other presentations herein). Jim could never understand what motivated or rewarded other people. He only understood what motivated him. This led to many conflicts and misunderstandings throughout his professional career. Ironically, the unusual combination of personality traits that drove him to scientific heights prevented him from forming and/or maintaining many long-term close collaborative relationships, and from being broadly admired in the same way his mentors (Baldwin, Hungate, and Bryant) were. Jim himself would occasionally reflect unfavorably on his own brusque manner and emotional distance. He once remarked that all the while he was at UC-Davis he envied fellow grad student Bob Stack, who apparently had a warm personal relationship with Hungate, his mentor. Jim said, "Stack would come into the lab and playfully remark, 'So what's the 'Gater been up to?' I could never seem to do that." Jim regarded Hungate, his microbiological mentor, with such awe that he would never presume to speak of him so casually, and he expected the same of his own students. Thus, throughout his career, even with all the professional accolades, Jim always felt himself on the outside looking in. Interestingly, in spite of that outsider status, Jim always regarded his time at Davis as a highlight of his life and he maintained that connection for years by bringing graduate students from Davis (Cotta and Russell, 1982; Martin and Russell, 1988) into his own lab.

Despite Jim's personality quirks, one of his unsung contributions to rumen microbiology was his role as a sounding board for other people's work. His natural skepticism pushed his colleagues to prove their particular cases more rigorously, and sometimes he could be a hard nut to crack. One of us (PJW) recalls one case in particular (Mouriño et al., 2001). There was an opinion among many that ruminal cellulose degradation slows dramatically at pH values below 6.0, the minimum growth pH of most cellulolytic bacteria. My students and I did some experiments which showed that the first-order rate constant of cellulose degradation by mixed ruminal microflora in

vitro varied with the initial pH of the culture, but that this value actually remained constant as pH declined, until pH reached nearly 5. I showed the data to Jim. He was not convinced, and wanted to see the phenomenon demonstrated in binary defined cultures (perhaps to help put it on a more mechanistic footing). So I demonstrated the same effect with pure cultures of three different cellulolytic species, when each was combined with a non-cellulolytic, cellodextrin-fermenting species (like *Selenomonas ruminantium* or Jim's favorite, *Streptococcus bovis* JB1 [a strain initialed after Jim himself]). As long as the noncellulolytic partner was present to consume cellodextrins produced by the cellulolytic partner, cellulose degradation continued unabated, until the pH reached around 5. I presented the new data to a still-skeptical Jim, and was exasperated by his response: "Are you sure you know how to measure pH?"

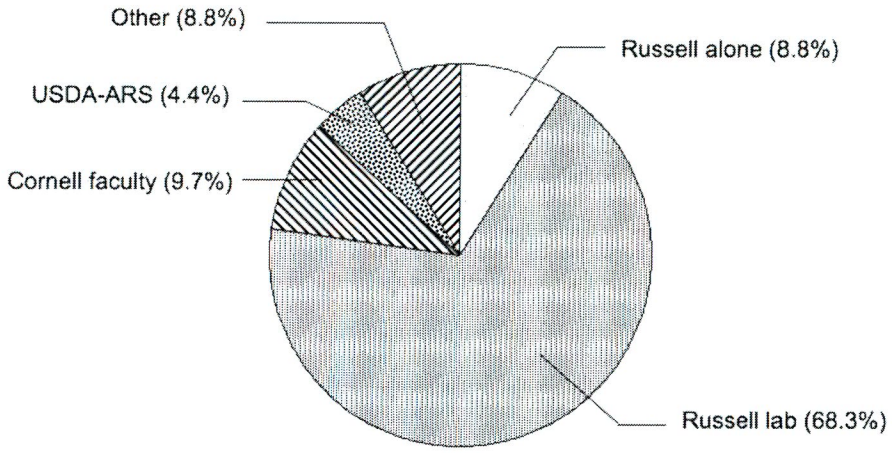
Jim's combination of natural skepticism and less-than-tactful expression was on full display whenever he was surrounded by his colleagues. For despite his aversion to travel, he was a frequent attendee and imposing presence at scientific meetings -- especially the biennial Conference on Rumen Function and the Cornell Nutrition Conference. Jim in particular hated flying, to the point that he often drove long distances to meetings, usually with lab members cowering or feigning sleep in the back seat as he motored nonstop from Ithaca to Chicago, or Indianapolis, or Maine, or wherever (Sample quote: "There's no need for a bathroom stop if you don't drink anything while we are driving"). At the meetings, Jim would drift from session to session, occasionally – if his scientific mind was sufficiently affronted – bestowing a question on a not-quite-unsuspecting colleague up on the podium. If Jim thought the response inadequate, he would often stretch out his arm at waist level, roll his palm upward ("Here it comes!" we all thought), sigh "Well…", and deliver some withering comment. Although this inability to "suffer fools gladly" would cause problems for Jim professionally, he maintained a deep and abiding respect for that surprisingly large number of colleagues whom he held in very high esteem, such as Milt Allison, for whom Jim named the genus *Allisonella* (Garner et al., 2004). Bob Hungate's passing in 2005 was a significant personal and professional blow to Jim because of the high esteem with which he regarded Dr. Hungate.

In spite of this sometimes-insensitive treatment of his colleagues, Jim recognized the need to bring new blood into our field, and he would never publicly embarrass graduate students from other labs. This generally supportive attitude came much to their mentor's surprise. Jim often welcomed students from various labs into his own lab for collaboration on a variety of projects. Additionally, having himself come to Cornell as an undergraduate from a farm background, there was always a position for undergraduate students to work in the Russell lab. If an undergraduate showed research promise, he or she was able to eventually get their own laboratory project and be co-author on manuscripts, if they could also get past Jim's unintentionally intimidating nature. When one undergraduate working on a project (Callaway et al., 1999) was called into Jim's office for "wisdom hour", she was struck mute with fear, unable to answer any questions due to her catatonic state. After about 2 months of this, Jim remarked, "She's really smart, she knows when to keep her mouth shut". Many of these research undergraduates went on to obtain advanced degrees in other laboratories (Bond et al.,

1999; Jarvis et al., 2000; Kurtovic et al., 2003).

Jim was a prolific writer (by our count, 227 journal articles, book chapters and review papers). Many of these papers were sole-author works of his own hand (Fig.1). As his co-authors soon found out, the world of Russell was full of

Figure. 1. Distribution of Dr. James B. Russell's 227 peer-reviewed journal publications, review articles and book chapters, based on co-authorship.



rules that put Jim in absolute control: Simple sentences (every sentence has a subject and a verb), direct wording (no need to be flowery), focused introductions, only three to five sentences in a paragraph. Tell a simple story so anyone can understand it. Keep your audience in mind at all times. Use gerunds often. Jim would frequently complain that one of us (TRC) did not know how to properly use gerunds, but educators in the deep South never discussed them, and to this day, I still don't know what a gerund is (Sorry, Jim). Jim's control of the writing process extended well beyond his own students, and seeped into his various outside collaborations. Regardless of how the dynamics of an experimental collaboration played out, there was never any doubt when it came to the writing: Jim was the boss, and writing with him, especially over the phone, often seemed like an endless, even Sisyphean, task. Over the course of hours, each sentence was evaluated, dissected, rearranged, discarded, resurrected and rehabilitated before it would meet his standards, Jim quickly abandoned the "Track Changes" option in Microsoft Word, probably because the result – an occasional word in black text bobbing up mournfully in a sea of red, struck-out text – was simply too dispiriting to his co-authors. He spent tremendous amounts of time in search of the perfect word, the perfect phrase, the perfect sentence. Here again, economy of language was paramount, and woe to the collaborator that brought him a sentence more than two lines long! Jim often quoted Blaise Pascal's famous line from 1657, "I have made this letter longer than usual, only because I have not had the time to make it shorter". With Jim Russell, you always took the time to make it shorter.

Despite this apparent rigidity, Jim's ability to teach scientific writing was unparalleled, even if the lessons were painful. Writing was a one-on-one effort. Every manuscript was a product of several weeks of writing, with slow progress made daily. When beginning as a graduate student, the retention of a word in a sentence was cause for celebration, but as one progressed, the deletions *en masse* were reduced. By completion of the time in Russell's workshop, writing had become part of a highly disciplined and organized process, an art rather than a science. Oddly enough, some of Jim's best creative writing emerged in the titles of his papers, where words like "spiraling" crept in to replace the simpler, utilitarian language to which he normally adhered (Russell and Hino, 1985).

Jim was convinced that his writing style was a big part of his ability to effectively use his experimental results to tie up the loose threads hanging in the existing literature. But, to us, the key to this success was that he seemed to know where all those loose threads were. One of the little known attributes that aided Jim in his scholarship and his quest to be known as the best rumen microbiologist of his generation was the fact that he had a pure eidetic (photographic) memory. This allowed him to have mastery of all of the past literature, which helped him see how it all fit together. Once, while we were listening to a talk on microbial degradation of protein in the rumen, Jim leaned over to one of us, pointed to a data slide on the screen, and whispered, "There's an almost identical figure on page 300 of Hungate's book!" Indeed it was so, and this was no fluke: Jim had a collection of more than 2,900 reprints, and could draw a figure from memory out of nearly any one of them. Nearly anytime that one of us (TRC) would come up with a "great experiment" or "what would happen if" question, Jim would say something like, "Jones did that in 1973 and showed...", and he would draw a good approximation of a graph; when you went and pulled the paper out and looked at it, the graph was nearly identical. This skill allowed Jim to appear to be a "witch" when discussing experiments. He could predict in advance how they would turn out, because he truly had seen it all before, and he kept those images in his mind always.

Jim believed that the big picture stories were the most crucial to the animal, but most especially to the farmer. One of these big stories that Jim was most proud of was the isolation of the obligate amino acid fermenting bacteria. The rate of ammonia production in the rumen was known to be greater than the individual rates of ammonia production of the known important ruminal bacterial species (e.g., *Prevotella*). The ionophore monensin primarily inhibits Gram positive organisms (Russell, 1987; Russell and Strobel, 1988; Russell and Strobel, 1989) yet most of the known ammonia-producing bacteria were Gram-negative, and the addition of monensin to cattle rations decreased ammonia production by nearly 50%. This was never effectively explained until Jim isolated the obligate amino acid fermenting bacteria that were monensin-sensitive and produced 50-fold more ammonia on a specific activity basis than did the more well-known ruminal species (Chen and Russell, 1989, 1990; Yang and Russell, 1993). This discovery led to recognition of the mode of action of monensin in cattle, and an appreciation of the potential role of these so-called " hyper-ammonia producing bacteria" in ruminal protein degradation (Attwood et al., 1998).

The passing of Jim Russell marks the end of an era in the field of rumen microbiology. Jim combined a rock-solid dairy background, a superb intellect and a single-minded obsession with rumen microbes to become the unquestioned leader in the field, a fitting inheritor of the mantle of Hungate and Bryant. Over the years rumen microbiology, like other disciplines of science, has changed immensely. "Individual investigator" science, at which Jim excelled, is giving way to grand-scale collaborations conducted among scientists of increasingly extreme specialization, using outlandishly expensive equipment. Microbial ecologists have exposed the limitations of culture-based studies, and molecular approaches are now *de rigueur* for obtaining the funding that will drive the acquisition of new scientific knowledge. Despite this, the "old-school" thinking of Jim Russell still has a place in the new molecular world: It is critical that we understand concepts such as kinetic order, specific activities and reaction rates and apply them to the torrent of new information that is being unleashed on rumen microbiologists through the development of pyrosequencing and the advanced techniques yet to come. Without a basic understanding of the mechanics, roles and even mathematics behind the ecology of the ruminant, further advances and understanding of the microecology and nutritional impacts of the microbial population will be delayed. Time, and science, march on. But none of these new realities will minimize the many contributions of Jim Russell, and of the students and colleagues he inspired.

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